Probing Transversity GPDs in Photo and Electroproduction of Two Vector Mesons

B. Pire[1] and L. Szymanowski[2]

[1] *CPhT, École Polytechnique CNRS, 91128 Palaiseau, France*

[2] *Soltan Institute for Nuclear Studies, Warsaw, Poland and University of Liège, Liège, Belgium*

Abstract

Electroproduction of two mesons well separated in rapidity allows the first feasible selective access to chiral-odd transversity GPDs provided one of these mesons is a transversely polarized vector meson ρ_T.

1 Introduction

The study of transversity [2] is of fundamental interest for understanding the spin structure of nucleons. Generalized Parton Distributions (GPDs) are the non-perturbative objects encoding the information about the quark and gluon proton structure in the most complete way. While the chiral even GPDs are probed in various hard exclusive processes, the access to transverse spin dependent chiral-odd GPDs has only recently been shown to be possible [3]. Since in the massless quark limit, chiral-odd functions must appear in pairs in a non-vanishing scattering amplitude, so that chirality flip encoded in one of them is compensated by another, a crucial point of our proposal is to use the transverse ρ meson chiral-odd Distribution Amplitude. We propose to use the transverse momentum of the first meson as the large scale needed to garanty the factorization of the GPD from a hard subprocess. The nature of the first meson depends on the energy range of the experiment. At large energy (e.g. in the Compass kinematics), diffractive production of a vector meson is much favored as compared to pseudoscalar meson production, and we thus focus on the process

$$\gamma^{(*)}(q)\ p(p_2) \to \rho^0_L(q_\rho)\ \rho^+_T(p_\rho)\ n(p'_2) \qquad (1)$$

while at lower energies (e.g. in the JLab kinematics), the process

$$\gamma^{(*)}(q)\ p(p_2) \to \pi^+(q_\pi)\ \rho^0_T(p_\rho)\ n(p'_2)\ , \qquad (2)$$

may be easier to detect. In both cases, one should also consider the reference process, *without* the transversity GPD

$$\gamma^{(*)}(q)\ p(p_2) \to \rho^0_L(q_\rho)\ \rho^+_L(p_\rho)\ n(p'_2)\ . \qquad (3)$$

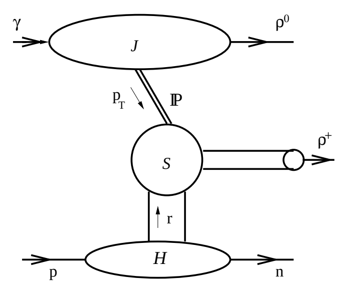

Figure 1: The process $\gamma^{(*)}_{L/T}\ p \to \rho^0_L\ \rho^+_{L/T}\ n$ in the QCD factorization approach.

In this presentation, we restrict to the large energy case where the off-shell exchanged object may be seen as a Pomeron (Fig. 1) and a complete computation is available [4]. The kinematics are described by the usual Mandelstam variables $s = (q + p_2)^2$, $s_1 = (q_\rho + p_\rho)^2$ and $s_2 = (p_\rho + p_{2'})^2$ and a skewedness parameter $\xi \approx \frac{s_1+Q^2}{2s}$. $\vec{p}$ is the transverse (with respect to q and p_2) momentum transfer in the two gluon (Pomeron) channel, Fig.

2. We have

$$s_1 \approx 2\xi s\ , \quad s_1 >> \vec{p}^{\,2}\ , \quad s_2 \approx \frac{\vec{p}^{\,2}}{2\xi}(1-\xi)\ .$$

2 The scattering amplitude

We have shown [3] that the Born term for the process (1) is consistently calculable within the collinear factorization method. The amplitude is the convolution of a hard (perturbative) part $T_H^q(x,u,z)$, two (non-perturbative) meson DAs $\phi_{\rho^+}(u)$ and $\phi_{\rho^0}(z)$ and the (non-perturbative) GPDs of the target $H^q(x,\xi,0)$, written as an integral over the longitudinal momentum fractions of the quarks

$$\mathcal{M} \sim \sum_{q=u,d} \int_0^1 dz \int_0^1 du \int_{-1}^1 dx \\ T_H^q(x,u,z)\, H^q(x,\xi,0)\phi_{\rho^+}(u)\phi_{\rho^0}(z) \quad (4)$$

The hard part $T_H^q(x,u,z)$ is described by 6 diagrams (Fig. 2). and the hard scale is the "Pomeron" virtuality $p^2 = p_T^2 = -\vec{p}^{\,2}$

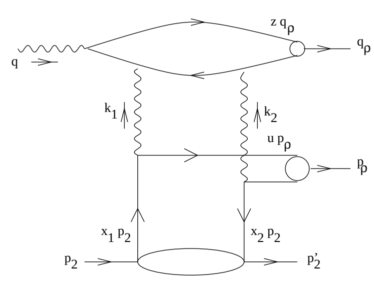

Figure 2: One of the 6 diagrams contributing to the scattering amplitude.

The longitudinal $\rho_L^0(q_\rho)$ or $\rho_L^+(p_\rho)$ distribution amplitudes (DAs) are defined from

$$\langle 0|\bar{q}(-x)\gamma^\mu q(x)|\rho_L^0(q_\rho)\rangle \\ = q_\rho^\mu f_\rho^0 \int_0^1 du\; e^{i(1-2u)(q_\rho x)}\phi_{||}(u) \quad (5)$$

with $\phi_{\|}(u) = 6u\bar{u}$ $\quad f_{\rho_L^0} = 216 \pm 5\,MeV$ $f_{\rho_L^+} = 198 \pm 7\,MeV$ while the transverse $\rho_T^0(p_\rho)$ DA is

$$\langle \rho_T(p_\rho,T) \mid \bar{q}(x)\sigma^{\mu\nu}q(-x) \mid 0\rangle = i f_\rho^T \quad (6) \\ \left(p_\rho^\mu \epsilon_T^{*\nu} - p_\rho^\nu \epsilon_T^{*\mu}\right)\int_0^1 du e^{-i(2u-1)(p_\rho x)}\,\phi_\perp(u)$$

with$\phi_\perp(u) = 6u\bar{u}$ $\quad f_{\rho_T^+} = 160 \pm 10\,MeV$

The transversity GPD is a non diagonal matrix element of the nonlocal operator

$$\hat{O}_T = \bar{q}(-\frac{z}{2})\, i\sigma^{+\,i}\, q(\frac{z}{2})$$

$$\int \frac{dz^-}{4\pi} e^{ixP^+z^-}\langle N(p_{2'},n)|\hat{O}_T|N(p_2,n)\rangle \quad (7) \\ = \frac{1}{2P^+}\bar{u}(p_{2'},n)i\sigma^{+\,i}u(p_2,n)H_T^q(x,\xi,t) + ...$$

Not much is known about such a non perturbative object, and different plausible models will yield quite different counting rates. We have used two models: we generalized the meson pole model by Gamberg et al [6] to the kinematics with GPDs and a model by Scopetta [7] based on the bag model. The resulting GPDs are very different as seen on Fig. 3.

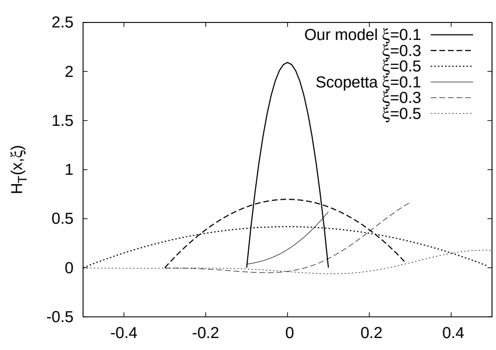

Figure 3: The transversity GPD H_T in the ERBL region in the meson pole model and in the model of Ref. [7].

The reference process with ρ_L^+ involves usual (but still largely unknown) non-polarized nucleon GPDs, constructed from the operator $\hat{O} = \bar{q}(-\frac{z}{2})\,\gamma^+\,q(\frac{z}{2})$

3 Results and conclusions

Fig. 4 and in Fig. 5 show the photoproduction cross sections for the reference process (3) and for process (1) with the transversity GPD described by the meson pole model.

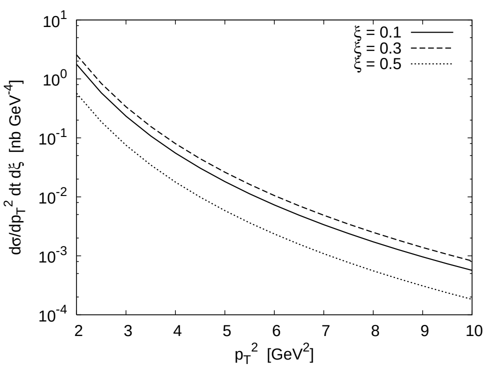

Figure 4: The cross-section for the reference process of photoproduction of ρ_L^0 and ρ_L^+.

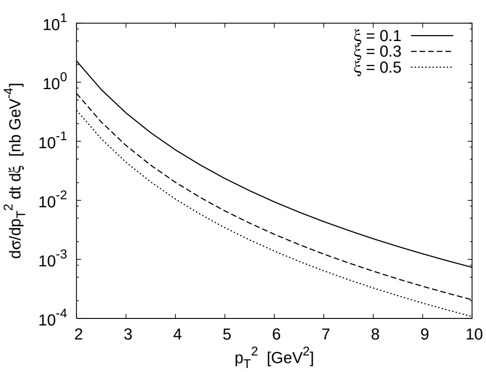

Figure 5: The cross-section for the photoproduction of ρ_L^0 and ρ_T^+ with the transversity GPD modeled by the b_1 meson exchange.

We see that the magnitudes of the cross sections are quite sizable in both cases, and we can thus infer that an experiment like COMPASS can measure these processes and thus access for the first time the transversity GPD.

Let us note that by replacing in the above process ρ_T^0 by a real photon γ and using the chiral-odd photon DA one may probe the magnetic susceptibility χ of the QCD vacuum. Indeed the photon DA is defined by a similar correlator as the transversity GPD [8]

$$\langle 0|\bar{q}(0)\sigma^{\alpha\beta}\,q(x)|\gamma^{(\lambda)}(p)\rangle = ie_q\,\chi\,\langle\bar{q}q\rangle \qquad (8)$$

$$\left(\epsilon_\alpha^{(\lambda)}p_\beta - \epsilon_\beta^{(\lambda)}p_\alpha\right)\int_0^1 du\,e^{-iu(px)}\phi_\gamma(u,\mu)$$

where $\chi\,\langle\bar{q}q\rangle \approx 40 - 70\text{MeV}$

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